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Value of a laser guidance system for CT interventions: a phantom study

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Abstract. The aim of this study was to check the handling and usefulness of a laser puncture system. The laser has tacking optics and is fastened to a sledge with angle graduation. The sledge runs on a bar fixed to the computerized tomograph (CT) parallel to the scan level. By means of a phantom, three experienced and seven inexperienced physicians made punctures with and without laser, using varying angles in single and double angulation. The distance from needle tip to target was measured. The handling of the puncture system proved to be problem-free. With both single and double angulation, the measurement differences with and without support were so small among experienced puncturers that there was no significant difference, with the exception of one double angulation (10°/45°). Among the beginners, there was a significant difference ($P < 0.001$, $P < 0.05$), with both single and double angulation. The accuracy of the beginners improved with use of the laser; experienced puncturers may profit from practice with small and hard-to-reach focuses. In terms of educational benefits, the laser guidance system offers great advantages and increased confidence for beginners.

Key words: CT – Intervention – Laser – Phantom study – Biopsy

Introduction

Percutaneous puncture (e.g., biopsy, drainage, lesional application of drugs) is becoming increasingly common in the daily work of the interventional radiologist. Punctures are performed with the guidance of ultrasonics, fluoroscopy, or computed tomography (CT). If ultrasonic methods fail to determine a localization, or if a difficult anatomical situation makes a safe, ultrasonically-guided puncture impossible, puncture should be performed using CT. The result is directly dependent on the size of the pathological finding, its anatomical situation (surrounding, access, depth), movement (patient, examiner), and on the pathological consistency of the findings. Errors may also occur in the choice of puncture site, its transmission, and the observance of depth. Frequent corrections of positioning should be avoided. In the lung, in particular, complications clearly increase, whereas the diagnostic yield decreases [1–3]. Thus, if there is even slight pneumothorax, the possibility of puncture in the lung is excluded, since the needle, guided in a forward direction, pushes the pleura, thus changing the position of the intrapulmonary-located focus.

Next to stereotactic systems, which certainly require costly hard- and software [4–10] there are easily expandable laser-puncture supports with no additional soft- and hardware, which should reduce, or even avoid, the above-mentioned transmission errors.

The aim of this study was to show the advantages of one of these systems over biopsy without guidance in a comparison of experienced and inexperienced users.

Materials and methods

We tested a laser-guided puncture support system (Partner-Diagnostica, Markt-Indersdorf, Gemany), consisting of a light source mounted on a rail, which can be installed on all standard CTs (Fig. 1a). The light source consists of two laser diodes. The device can rotate around its axis (Fig. 1b) and enables an exact graduation.

To check accuracy with and without puncture support, the following experimental conditions were set up: A semicylindrical phantom of foam was punctured. There were 5-mm boreholes in the center of its underside, representing the targets to be hit. To exclude errors in choosing the puncture site due to the transmission of the CT data, entry points were given on the surface of

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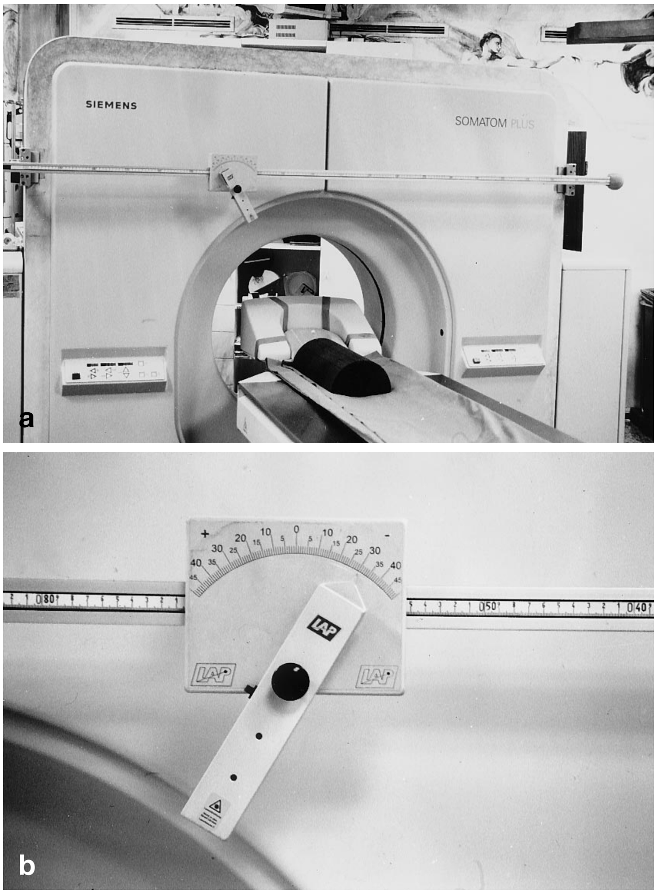

Fig. 1 a,b. The laser guidance system fixed on the computed tomograph (CT) (Somatom Plus S; Siemens, Germany). The semicylindrical phantom lies on the CT table

the phantom. Four entry points were given in the puncture layer of the target with angulations of 0°, 15°, 30°, and 45°, respectively. Two entry points demanded a double angulation of 15° and 45° in the puncture layer, and 10° in the sagittal plane. Finally, two other entry points demanded double angulations of 15°/20° and 45°/20°, respectively (Fig. 2). Thus, in total, eight entry points were given. Ten physicans performed two punctures each (one with and one without the laser support system) on each of the points. A total of 160 punctures were performed.

In order to assess the effect of the laser system, we had to minimize the effect of learning between the puncture with and the puncture without the use of the laser. The first puncture was carried out with and the second without laser guidance. There was an interval of 3 days between the two different kinds of puncture.

The punctures were made without correcting the position and the phantom was completely perforated in order to strike the entry of the boreholes on the underside of the phantom. After this, the distance between the center of the borehole and the needle tip was measured to determine the accuracy of the puncture.

On the assumption that single deviations from needle tip to borehole center follow a Gaussian distribution, we used the *t*-test for paired single spots. We checked whether the middle deviations using laser-puncture support were significantly different to those without. The analyses were carried out separately for experienced puncturers and beginners. The control CT scans were performed as follows: 135-kV tube voltage, 255 mAs, conventional mode with 5-mm collimation.

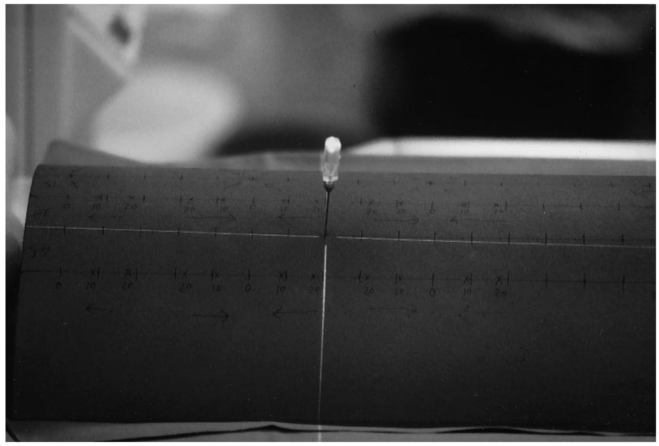

Fig. 2. The semicylindrical phantom with puncture needle in place. The laser cross is correctly positioned on the back of the needle

Results

For each instance of differing experimental conditions (puncture angle with and without puncture support), Table 1 shows mean values with standard deviation of the distance between the puncture needle and the center of the borehole in millimeters. Table 2 (beginners) and Table 3 (experienced group) present the mean values of difference with and without laser-puncture support; the larger the deviation's mean value, the greater the advantage offered by the laser-puncture support. Tables 2 and 3 also show the confidence interval of 95 % for the respective mean values of difference, as well as for their significance. Such differences are considered as significant when $P < 0.05$ (P = alpha-errors).

The deviations to the center of experienced puncturers ($n = 3$) with single angulation appeared to be between 2 and 4 mm (maximum deviation 5 mm with 45°), if no puncture support was used. Using the puncture help, the middle deviation proved to be between 1.7 and 2.3 mm (maximum deviation 4 mm with 45°; see Table 1). Accuracy increased on average to a maximum of 1.7 mm (45°) with the use of the laser-puncture support. The measured differences with and without support were so small among experienced puncturers that there was no statistical significance (Table 3).

With the experimental condition in which double angulation is used, clear deviations to the center appeared without puncture support and raising angles. The deviations fluctuated on average from 5.4 mm (10°/15°) to 24 mm (20°/45°). The maximum deviation was 29 mm (20°/45°; see Table 1). By using the laser, the deviations

Table 1. Results of experienced ($n = 3$) and unexperienced ($n = 7$) puncturers with and without laser

Angle	Condition (laser)	Deviation to center of boreholes (mm)	
		Experienced Mean value/ standard deviation	Unexperienced Mean value/ standard deviation
0°	Without	2.7/0.6	3.9/2.5
	With	1.7/0.6	1.9/1.2
15°	Without	2.0/1.7	16/7.7
	With	2.3/1.5	3.1/0.7
30°	Without	2.3/0.6	12.4/9.4
	With	2.0/0.0	5.0/3.5
45°	Without	4.0/1.0	12.6/7.3
	With	2.3/2.1	3.6/1.7
10°/15°	Without	5.3/2.1	27.0/6.6
	With	2.3/2.1	2.7/1.3
10°/45°	Without	14.3/3.1	20.7/1.3
	With	5.7/1.2	3.7/3.5
20°/15°	Without	13.0/9.6	18.4/10.0
	With	4.3/3.2	5.3/1.9
20°/45°	Without	24.0/4.6	24.4/13.8
	With	7.0/6.1	5.4/1.0

Table 2. Increase in accuracy among the group of beginners ($n = 7$)

Angle	Differences with/without laser (mean values in mm)	Confidence interval (95%; values in mm)	Significance (t-test)
0°	2	−0.2–4.2	ns
15°	12.9	5.6–20.1	($P < 0.01$)
30°	7.4	−0.4–15.3	ns
45°	9	2.2–15.8	($P < 0.05$)
10°/15°	24.3	18–30.6	($P < 0.01$)
10°/45°	17	8.1–25.9	($P < 0.01$)
20°/15°	13.1	4.6–21.6	($P < 0.01$)
20°/45°	19	6.4–31.6	($P < 0.05$)

Table 3. Increase in accuracy among the group of experienced puncturers ($n = 3$)

Angle	Differences with/without laser (mean values in mm)	Confidence interval (95%; values in mm)	Significance (t-test)
0°	1	–	–
15°	−0.3	−8.1–7.5	ns
30°	0.3	−1.1–1.8	ns
45°	1.7	−3.5–6.8	ns
10°/15°	3	–	–
10°/45°	8.7	2.9–14.4	($P < 0.05$)
20°/15°	8.7	−12.5–29.8	ns
20°/45°	17	−8.2–42.2	ns

to the center were clearly smaller. The middle deviation fluctuated between 2.3 mm (10°/15°) and 7 mm (20°/45°).

The maximum deviation was 14 mm (20°/45°; see Table 1); accuracy increased 3 mm (10°/15°) to 17 mm (20°/45°; see Table 1). Although for every puncture with support there was an improvement, statistical evaluation showed no significant difference between both procedures for experienced puncturers (except the experimental arrangement with 10°/45°; see Table 3).

Comparing the group of beginners with the experienced group, the beginners without laser guidance ($n = 7$) punctured the experimental arrangements with single angulation (15°, 30°, 45°) and with double angulation (10°/15°) worse than the experienced group. Although deviations to the center seemed on average to be clearly greater among the beginners than among the experienced group (e.g., 10°/15°: 27 mm compared to 5.3 mm) at 0°, 10°/45°, 20°/15° and 20°/45°, there was no statistically significant difference. Whenever the laser-puncture support was used, the results among beginners and experienced puncturers were nearly the same (two-sample t-test; $P < 0.05$).

Without laser guidance, the deviations among beginners with single angulation fluctuated on average between 3.9 and 12.6 mm, the maximum deviation being 30 mm (30°). By using the puncture support there were middle deviations from 1.9 to 3.6 mm, with a maximum deviation of 11 mm (30°; Table 3). The increase in accuracy was by 2–13 mm and significant for 15° and 45° (see Table 2).

The needle tips deviated under the condition of double angulation without laser using to the center on average between 18.4 and 27 mm, the maximum error being 51 mm. By using the puncture support, deviations were between 2.7 and 5.4 mm. The maximum deviation was 11 mm (10°/45°; see Table 1). The accuracy of laser-supported puncture increased on average by between 13.1 and 24.3 mm. This improvement was statistically significant for all experimental conditions (see Table 2).

Discussion

Well-known stereotactic systems effectively reduce malpositioning of puncture needles, corrections in positioning, and related complications. The disadvantage of these systems is the need for complex equipment in the CT room. Also, specific software is required [4, 5, 7–9, 11]. With some systems it is necessary to fix the device to the patient [12, 13], while others need mechanical needle guidance [10, 13]. With laser-supported systems, mechanical guidance is replaced by laser beams. In systems described in the literature, the puncture angle can be controlled on only one level in some, while others need costly equipment [5, 7, 14]. With the compact laser-puncture support, the puncturer is partially hindered [15, 16]. We examined the value of a laser-guided puncture support based on a phantom. The puncture accuracy decreased with increased angle, especially at double angulation. Using the laser-guided puncture support in all groups, a clear increase in accuracy was observed. The least advantage offered by the puncture support was observed among the group of experienced puncturers under simple conditions. Here, their primarily very good results could only be slightly improved upon (no

statistically significant difference). The clearest advantage of laser-guided puncture support was found among the beginners with double angulation: The primarily high deviations (over 20 mm from the destination point) were clearly improved upon, so that a successful puncture could be expected. Under double angulation using the puncture support, no differences in accuracy were found in either group.

We would like to illustrate our measurement results by demonstrating the accuracy of a fictitious focus: We used a small focus with a diameter of 2 cm according to our puncture results. Experienced puncturers with double angulation would have hit the focus on only four out of 12 attempts if no laser had been used; with laser assistance, the focus would have been hit 11 times. Without laser assistance, the beginners would have hit on two out of 28 attempts, while with the help of a laser support, successful hits would have totalled 27.

The disadvantage of the system tested is the relatively short distance between the laser and the surface of the patient, which makes puncture more difficult. This holds, in particular, in the case of sterility.

For punctures requiring axial angulation of greater than 50 °, it is necessary to reposition the patient, reaching angles of below 50 °. The limitation of longitudinal angulation is caused by the tilt of the gantry (± 20–25 °).

Although the time element is not included in our evaluation, we can postulate, on the basis of the clinical experience we have gained, that punctures not only became safer, but also faster. The use of apparatus (adjustment of previously defined angles) makes it necessary for the examiner to make careful preparations on the basis of the localization scans. This is believed to be leading to a reduction in positioning corrections and fewer complications. Even small, deep, localized findings can often be punctured without problems. Laser sight only has a slight influence on malpositioning through patient movement, varying inspiratory positions, and tissue consistency of the focus or puncture path.

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